USAFOEHL REPORT

88-065EH0193DAC



# Evaluation of Polyurethane Resins Used for Rapid Runway Repair Operations, Tyndall AFB FL



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April 1988

Final Report



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SECURITY CLASSIFICATION OF THIS PAGE

# REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

| | |
|---|---|
| 1a. REPORT SECURITY CLASSIFICATION<br>UNCLASSIFIED | 1b. RESTRICTIVE MARKINGS<br>N/A |
| 2a. SECURITY CLASSIFICATION AUTHORITY<br>NA | 3. DISTRIBUTION/AVAILABILITY OF REPORT<br>Distribution is unlimited; approved for public release |
| 2b. DECLASSIFICATION/DOWNGRADING SCHEDULE<br>NA | |
| 4. PERFORMING ORGANIZATION REPORT NUMBER(S)<br>USAFOEHL Report 88-065EH093DAC | 5. MONITORING ORGANIZATION REPORT NUMBER(S) |
| 6a. NAME OF PERFORMING ORGANIZATION<br>USAF Occupational and Environmental Health Laboratory<br>6b. OFFICE SYMBOL (If applicable)<br>ECH | 7a. NAME OF MONITORING ORGANIZATION |
| 6c. ADDRESS (City, State, and ZIP Code)<br>Brooks AFB TX 78235-5501 | 7b. ADDRESS (City, State, and ZIP Code) |
| 8a. NAME OF FUNDING/SPONSORING ORGANIZATION<br>Same as 6a<br>8b. OFFICE SYMBOL (If applicable) | 9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER |
| 8c. ADDRESS (City, State, and ZIP Code) | 10. SOURCE OF FUNDING NUMBERS<br>PROGRAM ELEMENT NO. / PROJECT NO. / TASK NO. / WORK UNIT ACCESSION NO. |

11. TITLE (Include Security Classification)
Evaluation of Polyurethane Resins Used for Rapid Runway Repair Operations, Tyndall AFB FL

12. PERSONAL AUTHOR(S)
Isaac Atkins Jr., Capt, USAF, BSC

| 13a. TYPE OF REPORT | 13b. TIME COVERED | 14. DATE OF REPORT (Year, Month, Day) | 15. PAGE COUNT |
|---|---|---|---|
| Final | FROM 10-12 Aug 87 | April 1988 | 25 |

16. SUPPLEMENTARY NOTATION

| 17. COSATI CODES | | | 18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number) |
|---|---|---|---|
| FIELD | GROUP | SUB-GROUP | Polyurethane resins; PERCOL-X-58-47-2; Runway repair; Tyndall AFB; PERCOL-S100; Ashland resin 65-088 |
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19. ABSTRACT (Continue on reverse if necessary and identify by block number)

This report describes how the USAF Occupational and Environmental Health Laboratory determined ambient concentrations of the ingredients of PERCOL-S100, PERCOL-X-58-47-2 and Ashland Resin 65-088 during two simulated runway repair surveys. Results from the PERCOL-S100 survey indicated perchloroethylene would pose the greatest health risk to the workers while results of the PERCOL-X-58-47-2 and Ashland resin 65-088 survey indicated the ingredients of PERCOL-58-47-2 did not pose a significant health risk; however, the Ashland resin ingredients, particularly phenols, hydrocarbons and pyridine, could pose a risk to the health of the workers. Further evaluation is recommended.

| 20. DISTRIBUTION/AVAILABILITY OF ABSTRACT | 21. ABSTRACT SECURITY CLASSIFICATION |
|---|---|
| ☐ UNCLASSIFIED/UNLIMITED ☒ SAME AS RPT. ☐ DTIC USERS | UNCLASSIFIED |
| 22a. NAME OF RESPONSIBLE INDIVIDUAL<br>Isaac Atkins Jr, Capt, USAF, BSC | 22b. TELEPHONE (Include Area Code)<br>(512) 536-3216<br>22c. OFFICE SYMBOL<br>ECH |

DD Form 1473, JUN 86 Previous editions are obsolete. SECURITY CLASSIFICATION OF THIS PAGE



UNCLASSIFIED

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## I. INTRODUCTION

### A. Background

The capability to continue to operate from bomb-damaged airfields has become an increasing Air Force concern. The repair of airfield pavements damaged by enemy weapons must be completed rapidly after an attack to allow launch and recovery of combat aircraft. New developments in weapons technology and increased demands in aircraft operations make existing crater repair procedures inadequate.

The Air Force Engineering and Services Center (AFESC), Tyndall AFB FL was tasked to investigate several bomb damage repair materials. Of the several bomb damage repair materials investigated, the polyurethane materials PERCOL-S100, PERCOL X-58-47-2 and Ashland resin 65-088 offered the greatest potential for all-weather expedient repair. However, limited data were available on the occupational hazards associated with using these materials during rapid runway repair operations. Therefore, AFESC requested the U.S. Air Force Occupational and Environmental Health Laboratory (USAFOEHL) perform an industrial hygiene assessment of these materials. This entailed a review of available toxicological data on the ingredients contained in each material and collection of ambient samples of those ingredients during simulated repair operations.

During the period of 14-17 Oct 86, the USAFOEHL evaluated the hazards associated with using the "bucket-mix" method of PERCOL-S100. Results indicated perchloroethylene (PCE) would pose the greatest health risk to the workers. Recommendations were made to substitute PERCOL-S100 with a polyurethane material which does not contain PCE.

After further research and development, another version of PERCOL and an Ashland resin (both of which did not contain PCE) were selected by AFESC for another industrial hygiene assessment. During the period of 21-27 Jun 87, USAFOEHL evaluated the occupational hazards associated with using the "bucket-mix" method of PERCOL-X-58-47-2 and Ashland resin 65-088. The results indicated occupational exposure to the ingredients of PERCOL-X-58-47-2 did not pose a significant health risk to the workers; however, occupational exposure to the Ashland resin ingredients particularly phenols, hydrocarbons, and pyridine, could pose a risk to the health of the workers.

### B. Objective of Current Report

This report explains how the USAFOEHL determined ambient concentrations of the ingredients of PERCOL-S100, PERCOL-X-58-47-2 and Ashland resin 65-088 during two simulated rapid runway repair training surveys.

C. Survey Personnel

Major Mohammad A. Hossain, Consultant, Industrial Hygiene Engineer; Capt Isaac Atkins Jr., Consultant, Industrial Hygiene Engineer; 1Lt Kul B. Garg, Consultant, Industrial Hygiene Engineer; 2Lt Anthony Zimmer, Consultant, Industrial Hygiene Engineer; Sgt Michael Lazenby, Industrial Hygiene Technician

## II. METHOD AND RESULTS

A. PERCOL-S100

Equal volumes of component A and component B of each resin were mixed in a bucket (Figure 1). Each mixture was thoroughly mixed for approximately 30 seconds then poured into a spall (or crater) filled with aggregate (Figure 2). If properly catalyzed, the mixture hardens in one or two minutes (Figure 3). The test consisted of filling approximately twenty spalls with each resin during indoor and outdoor tests. The training session lasted approximately 40 minutes. Indoor and outdoor personal and area air samples of chlorinated hydrocarbons, methylene bisphenyl isocyanate (MDI), and aromatic hydrocarbons were collected. Refer to Table 1 for sampling protocol.

Both personal and area samples were collected in the mixing (Figure 4) and spall repair (Figure 5) areas. Personal samples were collected in the subject's breathing zone. As a precaution, all test subjects and observational personnel wore full-face air-purifying organic cartridge respirators. To simulate "worst case" and actual field exposure, samples were collected under three different environmental conditions: (1) closed unventilated building, (2) ventilated building, and (3) outdoors on the runway.

Closed unventilated building. This simulated "worst case" exposure. Indoor samples were collected in a 100'W x 200'L x 25'H hangar. The ceiling fan was turned off and all doors were closed. As shown in Table 2, the highest PCE levels (137 and 168 milligrams per cubic meter [$mg/m^3$]) were personal and crater area samples, respectively. Only personal sample 2 contained detectable levels of MDI. Personal sample 2 contained an 8-hour time weighted average (TWA) concentration of 0.006 $mg/m^3$ which is far less than the allowable MDI 8-hour TWA of 0.2 $mg/m^3$.

Ventilated building. During this test, the hangar doors were opened and the ceiling fan turned on to ventilate the building. A pedestal fan was placed in front of the sampling area to provide additional air circulation. Data are provided in Table 3. The PCE levels ranged from nondetectable to 302 $mg/m^3$. One personal sample was 119 $mg/m^3$ and the other was nondetectable. Crater and mixing area samples were measured at 72 and 302 $mg/m^3$, respectively.

Outdoors on the runway. Since PERCOL-S100 will be used outdoors on the runway, this test simulated actual field exposure. As shown in Table 4, the highest PCE level (146 mg/m$^3$) was found in the crater area. All areas contained detectable levels of MDI except the crater area. The MDI concentration for the crater area was reported to be less than 0.001 mg/m$^3$. Personal samples 1, and 2 and the mixing area reported MDI concentrations of 0.033, 0.032 and 0.032 mg/m$^3$, respectively.

The workers experienced a greater inhalation exposure from PCE than MDI during all three tests. The highest PCE exposure (302 mg/m$^3$) occurred during the ventilated building test. Also, the PCE levels averaged the highest (123 mg/m$^3$, with one sample nondetected) during the ventilated building test. On the other hand, the lowest PCE levels averaged 52 mg/m$^3$ during the outdoors test. In the crater area combined PCE levels averaged 128 mg/m$^3$ versus 115 mg/m$^3$ for the mixing area.

**Figure 1. Mixing Operation. Equal volumes of component A and component B of each resin were mixed in a bucket.**

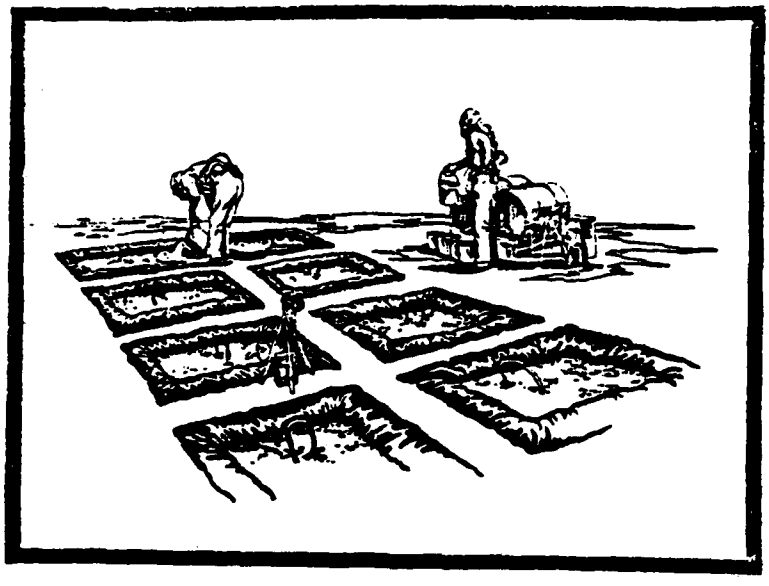

**Figure 2. Pouring Operation. Each mixture was thoroughly mixed then poured into a spall or crater filled with aggregate.**

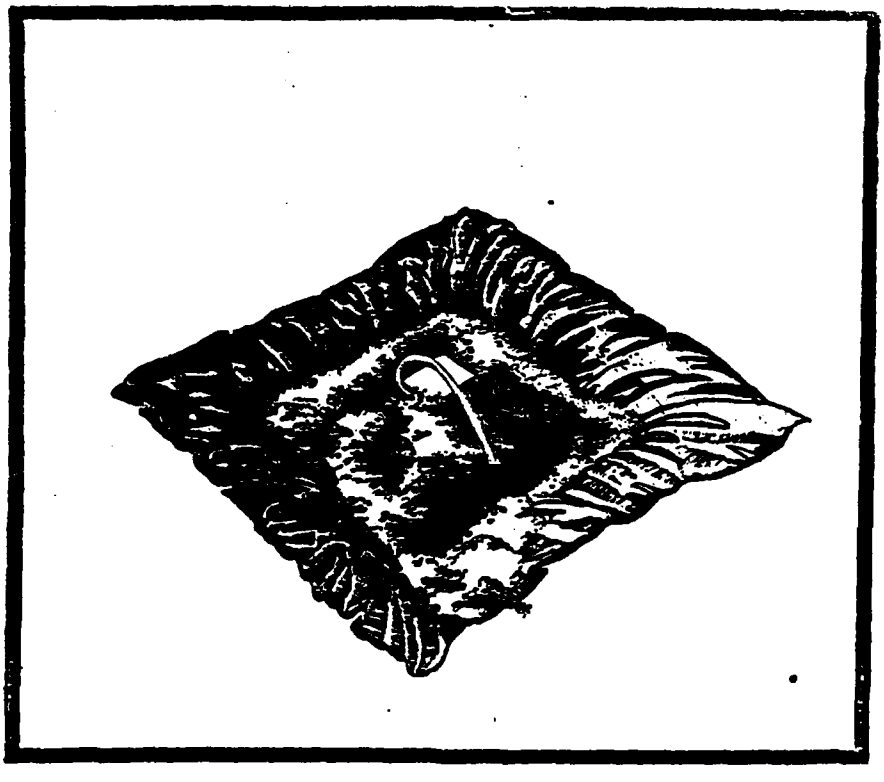

**Figure 3. Hardened resin. After the mixture has had time to catalyze it hardens in one or two minutes.**

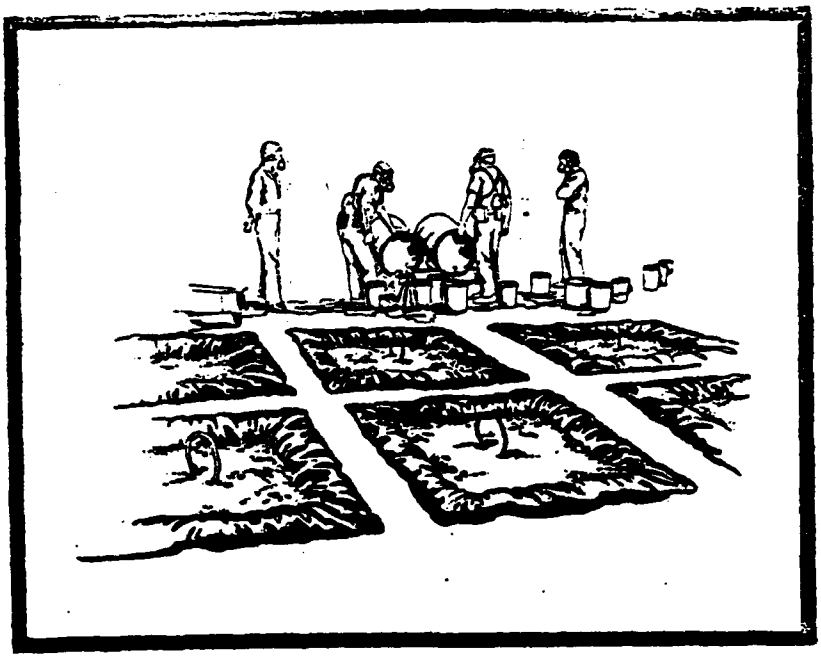

**Figure 4. Mixing area. Test subjects and observing personnel wore full-faced air-purifying organic vapor cartridge respirators.**

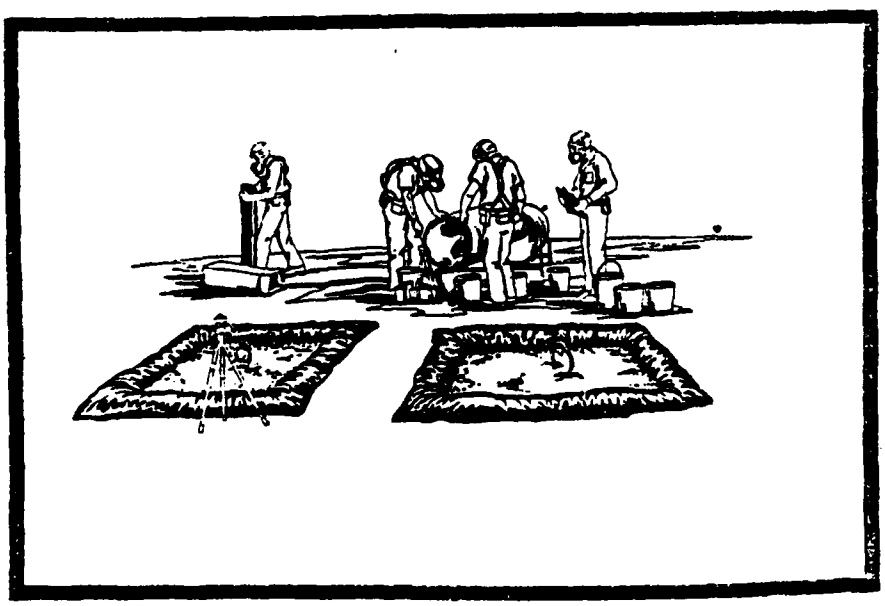

**Figure 5. Spill repair area. Note sampling apparatus. Sampling pumps were located downwind of spill repair area.**

## TABLE 1
## 14 Oct 1986, RAPID RUNWAY REPAIR OPERATIONS, TYNDALL AFB

*Sampling Protocol

| CHEMICAL NAME | SAMPLING METHOD | SAMPLING TIME(MIN) | FLOW-RATE USED(LPM) | VOLUME COLLECTED(LITERS) |
|---|---|---|---|---|
| PCE | charcoal tube | 40 | 0.2 | 8 |
| MDI | glass fiber filter | 40 | 2.0 | 80 |
| Aromatic Hydrocarbons | charcoal tube | 40 | 2.0 | 84 |

*Refer to USAFOEHL Sampling Guide 1985

## TABLE 2
## 14 Oct 1986, RAPID RUNWAY REPAIR OPERATIONS, TYNDALL AFB

@ Closed Building

| COMPONENT NAME | PEL mg/m$^3$ | LIMIT OF DETECTION (µg) |
|---|---|---|
| PERCHLOROETHYLENE (PCE) | 335 | 1.0 |
| METHYLENE BISPHENYL ISOCYANATE (MDI) | 0.2 | 0.1 |

| LOCATION | ECH ID No. | TIME (min) | CHEM NAME | SAMPLE CONC. mg/m$^3$ | 8-HOUR TWA CONC.(mg/m$^3$) |
|---|---|---|---|---|---|
| Mixing Area | EX860525 | 40 | PCE | 3 | 0.4 |
| | EZ860522 | 40 | MDI | ND* | |
| Crater Area | EX860527 | 40 | PCE | 168 | 21 |
| | EX860526 | 40 | MDI | ND* | |
| Personal 1 Sample | EZ860523 | 40 | PCE | 137 | 17 |
| | EZ860516 | 40 | MDI | ND* | |
| Personal 2 Sample | EZ860524 | 40 | PCE | 46 | 6 |
| | EZ860519 | 40 | MDI | 0.05 | 0.006 |

ND* -- Nondetected: MDI concentration less than 0.001 mg/m$^3$

@ Environmental conditions: temp = 67°F, barometer pressure = 767 mm Hg, relative humidity = 64%

**TABLE 3**
**14 Oct 1986, RAPID RUNWAY REPAIR OPERATIONS, TYNDALL AFB**

@Ventilated Building

| COMPONENT NAME | PEL, mg/m$^3$ | LIMIT OF DETECTION (µg) |
|---|---|---|
| PERCHLOROETHYLENE (PCE) | 335 | 1.0 |
| METHYLENE BISPHENYL ISOCYANATE (MDI) | 0.2 | 0.1 |

| LOCATION | ECH ID No. | TIME (min) | CHEM NAM | SAMPLE CONC. mg/m$^3$ | 8-HOUR TWA CONC.mg/m$^3$ |
|---|---|---|---|---|---|
| Mixing area | EX860543 | 41 | PCE | 302 | 38 |
| | EX860540 | 72 | MDI | 0.003 | 0.0004 |
| Crater area | EX860545 | 72 | PCE | 72 | 9 |
| | EX860544 | 72 | MDI | ND* | |
| Personal 1 sample | EZ860541 | 41 | PCE | ND** | |
| | EZ860534 | 41 | MDI | 0.012 | 0.002 |
| Personal 2 sample | EZ860542 | 41 | PCE | 119 | 15 |
| | EZ860537 | 41 | MDI | ND* | |

ND* -- Nondetected: MDI concentration less than 0.001 mg/m$^3$

ND** -- Nondetected: PCE concentration less than 0.1 mg/m$^3$

@ Environmental conditions: temp = 76°F, barometer pressure = 762 mm Hg, relative humidity = 45%, wind = calm

## TABLE 4
## 14 Oct 1986, RAPID RUNWAY REPAIR OPERATIONS, TYNDALL AFB

@Outdoors

| COMPONENT NAME | PEL, $mg/m^3$ | LIMIT OF DETECTION (µg) |
|---|---|---|
| PERCHLOROETHYLENE (PCE) | 335 | 1.0 |
| METHYLENE BISPHEHYL ISOCYANTE (MDI) | 0.2 | 0.1 |

| LOCATION | ECH ID No. | TIME (min) | CHEM NAME | SAMPLE CONC. $mg/m^3$ | 8-HOUR TWA CONC.$mg/m^3$ |
|---|---|---|---|---|---|
| Mixing area | EX860557 | 46 | PCE | 39 | 5 |
| | EX860551 | 34 | MDI | 0.032 | 0.004 |
| Crater area | EX860559 | 46 | PCE | 146 | 18 |
| | EX860558 | 46 | MDI | ND* | |
| Personal 1 sample | EZ860555 | 34 | PCE | 12 | 1.5 |
| | EZ860548 | 34 | MDI | 0.033 | 0.004 |
| Personal 2 sample | EX860556 | 34 | PCE | 12 | 1.5 |
| | EX860554 | 46 | MDI | 0.032 | 0.004 |

ND* -- Nondetected: MDI concentration less than 0.001 $mg/m^3$

@ Environmental conditions: temp = 67°F, barometer pressure = 766 mm Hg, relative humidity = 47%, wind = 5 to 15 knots

B. PERCOL-X-58-47-2 and the Ashland Resin

Another version of PERCOL (PERCOL-X-58-47-2) and Ashland resin 65-088 were evaluated using the same "bucket-mix" method as stated above. However, because limited amounts of these resins were available, this survey did not include a ventilated building test. The survey consisted of using a MIRAN 1B Infrared Analyzer, Century Organic Vapor Analyzer, and detector tubes to conduct area monitoring and charcoal tubes and glass fiber filters to conduct personal and area monitoring in the mixing and crater areas. Personal samples were collected in the test subjects' breathing zones. Ambient concentrations of the following chemicals were evaluated:

Ashland Resin - Phenols
Formaldehyde
Pyridine
Methylene bisphenyl isocyanate (MDI)
Naphtha (petroleum distillates)

PERCOL Resin - Methylene bisphenyl isocyanate
Naphtha (petroleum distillates)

A MIRAN 1B Portable Infrared Analyzer was used to monitor airborne concentrations of formaldehyde and phenol. The instrument used the characteristic wavelength of infrared absorption of formaldehyde and phenol to identify and quantify both compounds. The amount of infrared energy absorbed is proportional to the concentration of formaldehyde or phenol. The Century Organic Vapor Analyzer (OVA) analyzed the sampled air using a hydrogen flame to ionize the organic molecules. The DRAEGER detector tubes contain solid reagent chemicals which react with the sampled agents and gives a colorimetric indication of each agent's concentration. See Table 5 for sampling protocol and Table 6 for environmental conditions. Instruments were calibrated before and after each test using standards for formaldehyde, phenol and n-hexane for total hydrocarbons. To simulate "worst case" and actual field exposure, samples were collected in an unventilated building and outdoors on the runway.

Unventilated building. This simulated "worst case" exposure. Indoor samples were collected in a 100'W x 200'L x 25'H opened-end hangar. The ceiling fan was turned off. As shown in Table 7, the Ashland resin total hydrocarbon levels ranged from 16 to 46 $mg/m^3$. Traces of phenols and formaldehyde were also detected. The MDI 8-hour TWA concentrations were reported to be less than 0.0001 $mg/m^3$ for personal samples and 0.0008 $mg/m^3$ for area samples which is far less than the allowable MDI 8-hour TWA of 0.2 $mg/m^3$. On the other hand, Table 8 shows the direct reading instruments detected total hydrocarbon levels ranging from 180 to 280 parts per million (ppm) in the crater area and 50 to 70 ppm in the mixing area. Also, higher levels of phenols (ranging from 70 to 145 ppm in the crater area and 23 ppm in the mixing area) were detected along with traces of pyridine and formaldehyde.

**TABLE 5**
**21-27 Jun 1987, RAPID RUNWAY REPAIR OPERATIONS**
**TYNDALL AFB**
**Sampling Protocol**

| CHEMICAL NAME | SAMPLING METHOD | MAX/MIN SAMPLING TIME(min) | FLOW-RATE (LPM) | MAX/MIN VOLUME COLLECTED (L) | No.of SAMPLES |
|---|---|---|---|---|---|
| Phenols | midget impinger 0.1% N Sodium Hydroxide Sol. | 360/58 | 1.0 | 360/58 | 10 |
| Formaldehyde | midget impinger 1% Sodium Bisulfite Sol. | 360/58 | 1.0 | 360/58 | 10 |
| Pyridine | charcoal tube | 360/58 | 1.0 | 360/58 | 10 |
| Methylene Bisphenyl Diisocyanate | glass fiber Filter | 360/58 | 1.5 | 540/87 | 20 |
| Naphtha (petroleum distillates) | charcoal tube | 360/58 | 1.0 | 360/58 | 20 |

DIRECT READING INSTRUMENTS

| | | | |
|---|---|---|---|
| Phenols | Miran1B | (readings) | 35 |
| | Detector tube | | 10 |
| Formaldehyde | Miran 1B | (readings) | 35 |
| | Detector tube | | 10 |
| Pyridine | Detector tube | | 10 |
| Naphtha (petroleum distillates) | Century Organic calibration (n-hexane) Vapor Analyzer | (readings) | 70 |

**TABLE 6**
**21-27 Jun 1987, RAPID RUNWAY REPAIR OPERATIONS**
**TYNDALL AFB**

Environmental Conditions

| DATE/TIME | | WIND DIRECTION (nearest 10 )/ speed knots) | TEMP (°F) | *PRESSURE (inches Hg) | DEW PT (°F) | RELATIVE HUH (%) |
|---|---|---|---|---|---|---|
| 23 Jun | 0900 | 320/03 | 74 | 29.98 | 73 | 95 |
| | 1000 | 350/01 | 74 | 29.98 | 74 | 100 |
| | 1100 | 260/04 | 78 | 29.99 | 75 | 91 |
| | 1200 | 220/04 | 79 | 29.97 | 77 | 94 |
| | 1300 | 190/04 | 81 | 29.96 | 76 | 85 |
| | 1400 | 220/04 | 83 | 29.95 | 76 | 79 |
| | 1500 | 180/06 | 83 | 29.95 | 75 | 77 |
| | 1600 | 190/06 | 84 | 29.93 | 77 | 80 |
| | 1700 | 190/07 | 83 | 29.93 | 76 | 79 |
| 24 Jun | 0800 | 060/02 | 78 | 29.96 | 77 | 97 |
| | 0900 | 120/03 | 80 | 29.96 | 79 | 96 |
| | 1000 | 150/03 | 84 | 29.9§ | 78 | 83 |
| | 1100 | 200/04 | 85 | 29.98 | 76 | 72 |
| | 1200 | 210/04 | 85 | 29.98 | 77 | 78 |
| | 1300 | 200/06 | 85 | 29.96 | 76 | 75 |
| | 1400 | 210/06 | 85 | 29.94 | 77 | 78 |
| | 1500 | 210/06 | 86 | 29.93 | 77 | 75 |
| | 1600 | 210/07 | 86 | 29.93 | 77 | 75 |
| | 1700 | 220/05 | 86 | 29.90 | 77 | 75 |
| 25 Jun | 1000 | 240/08 | 85 | 29.91 | 78 | 80 |
| | 1100 | 240/08 | 86 | 29.92 | 79 | 80 |
| | 1200 | 250/08 | 86 | 29.91 | 78 | 77 |
| | 1300 | 270/09 | 85 | 29.91 | 77 | 77 |
| | 1400 | 200/08 | 84 | 29.89 | 77 | 80 |

* Uncorrected pressure
Prepared by AFESC/WE, Capt Mike Davenport

**TABLE 7**
**21-27 Jun 1987, RAPID RUNWAY REPAIR OPERATIONS**
**TYNDALL AFB**

Ashland Resin (Indoor Test)

| COMPONENT NAME | STD,(mg/m$^3$) | LIMIT OF DETECTION (µg) |
|---|---|---|
| PHENOL (PHE) | 19 | 10.0 |
| FORMALDEHYDE (FOR) | I.5 | 0.01 |
| PYRIDINE (PYR) | 15 | 10.0 |
| METHYLENE BISPHENYL DIISOCYANATE (MDI) | 0.2 | 0.1 |
| NAPHTHA (petroleum distillates) (HC) total hydrocarbons | 2000 | 6.0 |

| LOCATION | ECH ID No. | CHEM NAME | SAMPLE CONC. mg/m$^3$ | *8-HOUR TWA CONC.(mg/m$^3$) |
|---|---|---|---|---|
| Mixing Area | EX870452 | HC | 16 | 12 |
| | EX870453 | PYR | <1 | <0.8 |
| | EX870454 | MDI | <0.001 | <0.0008 |
| | EX870455 | FOR | 0.01 | 0.008 |
| | EX870456 | PHE | 0.05 | 0.04 |
| Crater Area Loc 1 | EX870457 | HC | 17 | 13 |
| | EX870458 | PYR | <1 | 0.8 |
| | EX870459 | HDI | <0.001 | <0.0008 |
| | EX870460 | FOR | 0.01 | 0.008 |
| | EX870461 | PHE | 0.004 | 0.003 |
| Crater Area Loc 2 | EX970462 | HC | 15 | 11.3 |
| | EX870463 | PTR | <1 | 0.8 |
| | EX870464 | MDI | <0.001 | <0.0008 |
| | EX870465 | FOR | <0.01 | <0.01 |
| | EX870466 | PHE | 0.03 | 0.02 |
| Personal 1 Sample | EZ870442 | HC | 46 | 6 |
| | EZ870443 | PYR | <1 | <.1 |
| | EZ870444 | MDI | <0.001 | <0.0001 |
| | EZ870445 | FOR | 0.04 | 0.004 |
| | EZ870446 | PHE | 0.14 | 0.02 |
| Personal 2 Sample | EZ870447 | HC | 30 | 3.6 |
| | EZ870448 | PYR | <1 | <0.1 |
| | EZ870449 | HDI | <0.001 | <0.0001 |
| | EZ870450 | FOR | 0.03 | 0.004 |
| | EZ870451 | PHE | 0.1 | 0.0l |

* 8 Hour TWAs calculations based on 6 hour exposure for area samples and 58 min exposure for personal samples.

**TABLE 8**
**DIRECT READING INSTRUMENT RESULTS**
**21-27 Jun 1987, RAPID RUNWAY REPAIR OPERATION**
**TYNDALL AFB FL**
Ashland Resin (Indoor & Outdoor Test)

| COMPONENT NAME | | STD, PPM |
|---|---|---|
| NAPHTHA (petroleum distillates) | (HC) | 500 |
| PYRIDINE | (PYR) | 5 |
| PHENOL | (PHE) | 5 |
| FORMALDEHYDE | (FOR) | 1 |

INDOOR TEST

| LOCATION | CHEM NAME | INSTRUMENT PEAK CONC. (ppm) |
|---|---|---|
| Mixing Area | HC (n-hexane) | 50-70 |
| | PYR | 2-5 |
| | PHE | 23 |
| | FOR | 2-3 |
| Crater Area | HC (n-hexane) | 180-280 |
| | PYR | 0 |
| | PHE | 70-145 |
| | FOR | 1-2 |

OUTDOOR TEST

| | | |
|---|---|---|
| Mixing Area | HC (n-hexane) | 8-20 |
| | PYR | 0 |
| | PHE | 4-7 |
| | FOR | 0.1-0.3 |
| Crater Area | HC | 30-35 |
| | PYR | 2-5 |
| | PHE | 6-9 |
| | FOR | 0.1-0.3 |

In contrast, as shown in Table 9, the PERCOL resin total hydrocarbon and MDI levels were reported to be less than 1.0 mg/m$^3$ and 0.001 mg/m$^3$, respectively. Personal samples 1 and 2 reported 8-hour exposures of less than 0.2 for total hydrocarbons and 0.0002 mg/m3 for MDI. The MDI levels were far less than the allowable MDI 8-hour TWA of 0.2 mg/m$^3$. Table 10 shows the direct reading instruments detected total hydrocarbon concentrations ranging from 2 to 4 ppm compared to 180 to 280 ppm for the Ashland resin.

Outdoors on the runway. This test simulated actual field exposure. As shown in Table 11, the Ashland resin test total hydrocarbon levels were 20 and 9 mg/m$^3$ for personal sample 1 and the mixing area, respectively. Traces of phenols and formaldehyde were also detected. The MDI 8-hour TWAs were reported to be less than 0.0001 and 0.0002 mg/m$^3$ for personal and area samples, respectively. This is far less than the allowable MDI 8-hour TWA of 0.2 mg/m$^3$. Table 8 shows the direct reading instruments detected total hydrocarbon levels ranging from 30 to 35 ppm in the crater area and 8 to 20 ppm in the mixing area. Lower levels of phenols (4 to 9 ppm) and formaldehyde (0.1 to 0.3 ppm) were also detected with measurable amounts of pyridine.

In contrast, Table 12 shows the PERCOL resin test reported only one sample with detectable amounts of hydrocarbons. We measured a concentration of 2 mg/m$^3$ for total hydrocarbons in the crater. The MDI levels were reported to be less than 0.001 mg/m$^3$. Table 10 shows the direct reading instruments measured the total hydrocarbon levels ranging from 2 to 4 ppm.

## III. DISCUSSION AND CONCLUSIONS

### A. PERCOL-S100

The AFESC requested an evaluation of occupational hazards associated with using the "bucket-mix" method of PERCOL-S100 during spall repair operations. The major chemical components of PERCOL-S100 were evaluated and we determined that chlorinated hydrocarbons, MDI, and aromatic hydrocarbons could pose a health risk to the workers. Samples were screened for chlorinated and aromatic hydrocarbon congeners. The results indicated trace levels of perchloroethylene (PCE) with no detectable levels of aromatic hydrocarbons (i.e., less than 0.006 mg/m$^3$). Subsequent samples were analyzed for PCE.

To calculate the 8-hour TWA for PCE and MDI, we assumed a 1 hour exposure period. An additional 20 minutes was added to the sampling time (40 minutes) to account for additional training time spent in the training area. As shown in Tables 2, 3, and 4, the MDI and PCE 8-hour TWAs were far below the American Conference of Government Industrial Hygienists (ACGIH) recommended exposures of 0.2 mg/m$^3$ for MDI and 335 mg/m$^3$ for PCE.

Tables 2, 3, and 4, also show the MDI and PCE concentrations did not correlate with expected results. The highest concentrations of MDI and PCE were expected during the closed unventilated test; however, the highest PCE concentration (302 $mg/m^3$) was found during the ventilated building test and the highest MDI concentration during the outdoors tests. Concentrations for personal samples 1 and 2 also varied widely over all three tests. For example, during the ventilated building test, personal sample 2 contained a PCE concentration of 119 $mg/m^3$ while personal sample 1 was nondetected (i.e., 0.1 $mg/m^3$). Also, personal sample 1 contained a MDI concentration of 0.012 $mg/m^3$ while personal sample 2 was nondetected (i.e., less than 0.001 $mg/m^3$).

**TABLE 9**
**21-27 Jun 1987, RAPID RUNWAY REPAIR OPERATIONS**
**TYNDALL AFB**
**PERCOL Resin (Indoor Test)**

| COMPONENT NAME | STD, ($mg/m^3$) | LIMIT OF DETECTION ($\mu g$) |
|---|---|---|
| METHYLENE BISPHENYL DIISOCYANATE (MDI) | 0.2 | 0.1 |
| NAPHTHA (petroleum distillates) (HC) total hydrocarbons | 2000 | 6.0 |

| LOCATION | ECH ID No. | CHEM NAME | SAMPLE CONC. $mg/m^3$ | *8-HOUR TWA CONC. ($mg/m^3$) |
|---|---|---|---|---|
| Mixing Area | EX870496 | HC | <1 | <0.4 |
| | EX870497 | MDI | <0.001 | <0.0004 |
| Crater Area LOC 1 | EX870498 | HC | <1 | <0.4 |
| | EX870499 | MDI | <0.001 | <0.0004 |
| Crater Area LOC 2 | EX870500 | HC | <1 | <0.4 |
| | EX870501 | MDI | <0.001 | <0.0004 |
| Personal 1 Sample | EZ870492 | HC | <1 | <0.2 |
| | EZ870493 | MDI | <0.001 | <0.0002 |
| Personal 2 Sample | EZ870494 | HC | <1 | <0.2 |
| | EZ870495 | MDI | <0.0001 | <0.0002 |

* 8-Hour TWA calculations are based on 3 hrs exposure for area samples and 83 min exposure for personal samples.

**TABLE 10**
**DIRECT READING INSTRUMENT RESULTS**
**21-27 Jun 1987, RAPID RUNWAY REPAIR OPERATION**
**TYNDALL AFB FL**
**PERCOL Resin (Indoor & Outdoor Test)**

| COMPONENT NAME | TWA STD, PPM |
|---|---|
| NAPHTHA (petroleum distillates) (HC) | 500 |

INDOOR TEST

| LOCATION | CHEM NAME | INSTRUMENT CONC. (ppm) |
|---|---|---|
| Mixing Area | HC | 2-4 |
| Crater Area | HC | 2-4 |

OUTDOOR TEST

| | | |
|---|---|---|
| Mixing Area | HC | 2-4 |
| Crater Area | HU | 2-4 |

**TABLE 11**
**21-27 Jun 1987, RAPID RUNWAY REPAIR OPERATIONS**
**TYNDALL AFB**
**Ashland Resin (Outdoor Test)**

| COMPONENT NAME | STD, ($mg/m^3$) | LIMIT OF DETECTION (µg) |
|---|---|---|
| PHENOL (PHE) | 19 | 10.0 |
| FORMALDEHYDE (FOR) | 1.5 | 0.01 |
| PYRIDINE (PYR) | 15 | 10.0 |
| METHYLENE BISPHENYL DIISOCYANATE (MDI) | 0.2 | 0.1 |
| NAPHTHA (PETROLEUM DISTILLATES) (HC) total hydrocarbons | 2000 | 6.0 |

| LOCATION | ECH ID# | SAMPLE CONC. CHEM NAME | $mg/m^3$ | *8-HOUR TWA CONC.($mg/m^3$) |
|---|---|---|---|---|
| Mixing Area | EX870477 | HC | 9 | 2.5 |
| | EX870478 | PYR | <1 | <0.3 |
| | EX870479 | MDI | <0.001 | <0.0002 |
| | EX870480 | FOR | 0.02 | 0.005 |
| | EX870481 | PHE | 0.04 | 0.01 |
| Crater Area LOC 1 | EX870482 | HC | 5 | 1.4 |
| | EX870483 | PYR | <1 | <0.3 |
| | EX870484 | MDI | <0.001 | <0.0002 |
| | EX870485 | FOR | 0.03 | 0.008 |
| | EX870486 | PHE | 0.03 | 0.008 |
| Crater Area LOC 2 | EX870487 | HC | 6 | 1.7 |
| | EX870488 | PYR | <1 | <0.3 |
| | EX870489 | MDI | <0.001 | <0.0002 |
| | EX870490 | FOR | 0.02 | 0.005 |
| | EX870491 | PHE | 0.03 | 0.008 |
| Personal 1 Sample | EZ870467 | HC | 20 | 2.4 |
| | EZ870468 | PYR | <1 | <0.1 |
| | EZ870469 | MDI | <0.001 | <0.0001 |
| | EZ870470 | FOR | 0.02 | 0.002 |
| | EZ870471 | PHE | 0.05 | 0.006 |
| Personal 2 Sample | EZ870472 | HC | <1 | <0.1 |
| | EZ870473 | PYR | <1 | <0.1 |
| | EZ870474 | MDI | <0.001 | <0.0001 |
| | EZ870475 | FOR | 0.02 | 0.002 |
| | EZ870476 | PHE | 0.12 | 0.01 |

* 8-Hour TWAs calculations based on a 2.2 hr exposure for area samples and 58 min exposure for personal samples.

**TABLE 12**
**21-27 Jun 1987, RAPID RUNWAY REPAIR OPERATIONS**
**TYNDALL AFB**
**PERCOL Resin (Outdoor Test)**

| COMPONENT NAME | STD, ($mg/m^3$) | LIMIT OF DETECTION (µg) |
|---|---|---|
| METHYLENE BISPHENYL DIISOCYANATE (HDI) | 0.2 | 0.1 |
| NAPHTHA (petroleum distillates) (HC) total hydrocarbons | 2000 | 6.0 |

| LOCATION | ECH ID No. | CHEM NAME | SAMPLE CONC. $mg/m^3$ | *8-HOUR TWA CONC.($mg/m^3$) |
|---|---|---|---|---|
| Mixing Area | EX870507 | HC | <1 | <0.3 |
| | EX870506 | MDI | <0.001 | <0.0003 |
| Crater Area LOC 1 | EX870509 | HC | 2 | 0.6 |
| | EX870508 | MDI | <0.001 | <0.003 |
| Crater Area LOC 2 | EX870511 | HC | <1 | <0.3 |
| | EX870510 | MDI | <0.001 | <0.0003 |
| Personal 1 Sample | EZ870502 | HC | <1 | <0.09 |
| | EZ870503 | MDI | <0.001 | <0.00009 |
| Personal 2 Sample | EZ870504 | HC | <1 | <0.09 |
| | EZ870505 | MDI | <0.001 | <0.00009 |

* 8-Hour TWA calculations are based on 2.25 hours exposure for area samples and 44 minutes exposure for personal samples.

Generally, PCE and MDI exposures did decrease during the outdoor tests except for the crater area. This test simulated actual field spall repair conditions. The concentrations decreased because the outdoor environment diluted the ambient concentrations. However, the outdoor environment will not guarantee a reduction in exposure. For example, wind currents may suddenly change, thereby directing the vapors in the face of the workers. The manufacturer stated, "hot environments may liberate more PCE vapors from the mixture." We did not validate this statement. The environmental conditions during each test are listed at the bottom of Tables 2, 3, and 4. We concluded that PCE exposures may increase or decrease depending on existing environmental conditions.

During the closed unventilated building test, employees located 10 to 15 feet away from the test area complained of headaches and chest tightness. The survey team and the test subjects experienced these symptoms even though the PCE and MDI exposures were reported to be far less than their respective 8-hour TWAs. We concluded that exposure to PERCOL-S100 may present some discomfort to sensitive individuals.

B. PERCOL-X-58-47-2 and the Ashland Resin

An industrial hygiene assessment of PERCOL X-58-47-2 and Ashland resin 65-088 indicated that formaldehyde, pyridine, MDI, and total hydrocarbons could pose a risk to the health of the workers. Direct reading instruments were used to monitor the workers' exposures. Additionally, personal and area air samples were collected in the mixing and spall repair areas. Results indicated occupational exposure to airborne concentrations of the ingredients in PERCOL X-58-47-2 did not pose a significant health risk; however, occupational exposure to the Ashland resin ingredients, particularly phenols, hydrocarbons, and pyridine, could pose a risk to the health of the workers.

As shown in Tables 7 and 11, the 8-Hour TWAs for the ingredients of the Ashland resin (i.e., phenol, formaldehyde, pyridine, MDI and total hydrocarbons) were far below their respective allowable 8-hour TWAs of 19 $mg/m^3$ for phenol, 1.5 $mg/m^3$ for formaldehyde, 15 $mg/m^3$ for pyridine, 0.2 $mg/m^3$ for MDI, and 2000 $mg/m^3$ for total hydrocarbons during the indoor and outdoor tests. However, Table 8 shows we detected peak concentrations of phenols, formaldehyde, and total hydrocarbons above one-half the Permissible Exposure Limit (PEL) for those chemicals. On the other hand, Tables 9, 10 and 12 show the ingredients of the PERCOL resin were well below one-half the PEL during both tests.

Industrial exposure to low level concentrations of phenol, pyridine, formaldehyde, and hydrocarbons may present a health hazard to the workers. For example, brief intermittent industrial exposure to vapor concentrations of 48 ppm of phenol (accompanied by exposure to formaldehyde) causes irritation of eyes, nose, and throat [1]. Also, chemical plant workers chronically exposed to 6 to 12 ppm of pyridine developed headache, vertigo, and nervousness [2]. Although higher concentrations of hydrocarbons (4000 to 7000 ppm) are necessary to cause symptoms of central nervous system depression, the reported hydrocarbons could act as a synergistic agent causing eye, nose, and throat irritation. Since the "bucket-mix" method involves mixing and pouring operations which release these chemicals in the workers' breathing zones, we conclude that these symptoms could occur if occupationally exposed to the ingredients of the Ashland resin.

## IV. RECOMMENDATIONS

A. PERCOL-S100

1. Recommend workers wear a National Institute of Occupational Safety and Health (NIOSH) approved full-face air-purifying organic vapor cartridge respirator during initial depolyment of PERCOL-S100 to the field. Recommend establishing a respiratory protection program which, as a minimum, meets the requirements of AFOSH Standard 161-1, Respiratory Protection Program and 29 CFR 1910.134. The respirators selected must be approved by the Mine Safety and Health Administration (MSHA) and NIOSH. These recommendations are based on the following findings: (1) under certain environmental conditions the workers could experience severe discomfort from exposure to low level PCE concentrations, (2) the PCE concentrations may increase or decrease depending on environmental conditions, and (3) we experienced and received reports of symptoms that indicated PERCOL-S100 could pose a risk to the health of the workers.

2. Recommend workers wear chemical protective gloves and clothing to eliminate skin exposure. Consideration should be given to utilizing disposable apparel, such as Tyvek Suits, because of the absorptive properties of PCE. Neoprene gloves and boots should be used because neoprene has been shown to be resistant to permeation by PCE. We provide these recommendations because we observed PERCOL-S100 spillage on the shoes and clothing of the workers during the mixing and pouring operations. This could result in skin irritation or dermatitis.

3. Recommend additional sampling be performed by base bioenvironmental engineering personnel during the initial depolyment of PERCOL-S100. Very little data are available on this product and more data are needed to accurately quantify the level of PCE exposure.

4. Recommend substitution of PERCOL-S100 with a polyurethane material which does not contain PCE. Another version of PERCOL-S100 and an Ashland product do not contain PCE. These two chemicals should be evaluated for possible use for spall repair.

B. PERCOL X-58-47-2 and the Ashland Resin

1. Recommend workers wear a NIOSH approved full-face air-purifying organic vapor cartridge respirator during initial depolyment of the Ashland resin to the field. No respirator protection is recommended for the PERCOL resin; however, base bioenvironmental personnel should be present during initial deployment of PERCOL to observe work practices. The M-17 gas mask is not recommended for routine peacetime use because it is not a MSHA/NIOSH approved respirator.

2. Recommend workers wear chemical protective gloves and clothing to eliminate skin exposure during use of both resins. Due to the content of hydrocarbons, these resins act as defatting agents. Repeated or prolonged skin contact may cause drying and cracking of skin. Tyvek suits and butyl rubber gloves are suggested for use.

3. Recommend additional sampling be performed by base bioenvironmental engineering personnel during the initial deployment of either or both resins.

## REFERENCES

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